9 - The extended mind thesis: can it be explored synthetically?

Selective pressures towards the evolution of extended memory

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It is generally agreed among the scientific community that a crucial transition occurred around 50 kya (Ambrose, 1998; Mellars, 2006b). On the one hand, populations of genetically and anatomically modern humans suffered a major geographical dispersal, and on the other the archaeological record of the Upper Paleolithic indicates a proliferation of distinctive signs of a cognitive explosion such as artworks, bone tools, and lunar calendars (e.g., Marshak, 1991). It has been suggested that these changes eventually lead to a unique entanglement of cognitive, cooperative, and communicative traits which are at the center of what it is often called cumulative cultural evolution (CCE). Its main function is to allow humans to share and accumulate information both horizontally (i.e., among members of a group) and vertically (i.e., from parents to offspring). CCE strongly relies and depends on a set of external artefacts such as language and tools. Its main benefit is its "ratchet effect" that allows humans to store and transmit the knowledge acquired across thousands of generations (Tomasello, 1999; Tomasello et al., 1993) without a recurrent cost. As a consequence, the adaptation rate due to cultural evolution is orders of magnitude faster when compared to the traditional genetic mechanism: "we fly using planes, not wings" (Cavalli-Sforza and Feldman, 1983).

Natural selection and the extended mind thesis

Darwin's theory of evolution (1859) explains how species continually adapt to their environment — which encompasses not only physical features but also other organisms — by means of natural selection. Environment in this context should be defined as the set of external physical and social features that can impact on the survival of an organism: e.g., food distribution, physical parameters, population density, etc. Individuals who are better adapted to their particular environment would necessarily have a higher probability of reproduction. Since one of the main drivers of natural complexity is natural selection, an evolutionary approach can potentially be a fruitful one. Questions such as does it make sense from an evolutionary point of view? And which selective pressures gave rise to it? If the answer to these questions is a negative one it is likely that the phenomenon is not an adaptation and hence epiphenomenal (i.e., a by-product of the adaptation process).

Proposed by Clark and Chalmers in 1998, the extended mind thesis (EMT) blurs the traditional boundary between mind and environment, and suggests that mind can extend beyond the body's boundaries by actively using external artefacts. In particular, the authors proposed that external artefacts can be considered part of an extended cognitive system if they are functionally equivalent (Clark and Chalmers, 1998). The canonical example is memory and how the use of an external artefact --- physical in this case --- such as a notebook can perform the same function as its biological homologue. However, non-physical artefacts, such as language, can also extend the boundaries of the mind.

An evolutionary model of external memory

Arguably, a synthetic approach which allows us to gain insights into the EMT should not be different to the approach we would take for any other natural phenomena, such as the evolution of cooperation (e.g., Axelrod, 1987), the evolution of signalling and sex (Maynard-Smith, 1982), or the evolution of communication (e.g., Quinn, 2001). These phenomena have all been largely studied through synthetic models — mathematical, game-theoretic, or computational. It is crucial to find out whether the proposed explanation for a given phenomenon is evolutionarily plausible by modelling the progress of natural selection given specified environmental conditions (i.e., niches) that may have selected for the behaviour in question. In any event, better knowledge of the selection pressures associated with these primeval environments is a valuable product of the modelling exercise.

We propose a very simple conceptual agent-based evolutionary model that illustrates how different environmental conditions can select for memory and extended memory.

The model consists of a population of artificial agents in a world filled with some natural resources (i.e., food) which the agents can collect in exchange for energy (i.e., fitness). Natural resources disappear from the grid as agents collect them. Every agent has an internal memory of limited size that allows it to remember food locations. The size of this memory is genetically specified; memory sizes are randomly allocated for the starting generation. The internal memory has a small metabolic cost associated with it, and this cost is directly proportional to the size of the memory. Agents also have a second costly gene which controls whether or not the agent is able to store infinite food positions in an external artefact (think of a notebook with infinite pages). The cost of the external memory gene is much higher than the internal one. When an agent jumps into a food position its energy increases by a certain value and the location of the resource is automatically added to its memory (if its memory size is non-zero). Agents move depending on the content of their memory; if their memory is empty they jump from their current position to a new randomly selected location. After a period of time a new population is created by selection and asexual reproduction of the best performing agents (i.e., depending on how much food they have collected minus the associated costs of the memory genes). During the reproduction process there is a small probability that the new clone may experience a random change (i.e., mutation). The new agents inherit the memory contents of their parents and the natural resources are replaced, so the whole process is repeated for a specific number of times generations. For clarity's sake it is important to stress that an alternative setup could have chosen, in which the memory contents would not been inherited and the resources would be replaced during the generations, however this does not invalidate the main idea.

A first insight is that if the food locations change at each generation the memory trait will rapidly go extinct: in such a scenario having costly memory is pointless.

A second insight from the same model is that selection for having an external memory module will only occur when the time scale is long enough to select for large amounts of memory. The costs --- in both biological fitness and time --- of increasing the internal memory would be too expensive. However, once the external module is selected its cost remains constant. In the long run, the external module is the only plausible option to store large amounts of memory efficiently.

Although the model is very simple, it illustrates how the internal complexity of the agent (i.e., memory vs. non-memory) is coupled with the environmental complexity (i.e., spatio-temporal food distribution patterns) (Godfrey-Smith, 1998; Ashby, 1957). In addition to this, it also illustrates how externalist versions of pre-existing cognitive traits — e.g., external memory — can be selected even when their costs in biological fitness are much greater that their internal analogous. Taking all the above-mentioned into consideration, computational models and more precisely evolutionary agent-based models can be valuable tools to approach the extended mind hypothesis.

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